U.S. Rural Electrification Administration.

DEMONSTRATION OF THE EFFECT OF VOLTAGE DROP ON THE OPERATION OF ELECTRICAL EQUIPMENT

A. The attached diagram and bill of material illustrates equipment which may be assembled and used for demonstrating the relation of adequate wiring to the operation of electrical equipment. Three things may be demonstrated with the set-up shown:

(1) The effects of voltage drop on the operation of electrical equipment.
(2) Some of the causes of voltage drop.
(3) The operation of fuses and circuit breakers in providing over-load protection.

B. The Demonstration Equipment

The diagram illustrates the following equipment:

(1) Twenty-five to 50 feet of heavy-duty flexible cord for connecting the demonstration to a source of electricity. The cord shown is 10/2 but 12/2 may be satisfactorily used. One end of this cord is connected to the line terminals of load center equipment. The other end is connected to a heavy duty 2-prong plug for connection to any receptacle source of 110-120 volt power. A short length of heavy duty cord may be added with a cord receptacle on one end and battery clips with insulated grips on the other. This supplementary piece of cord would provide for using the clips to connect directly to the service drop or the building load center when the circuits supplying the convenience receptacles lack capacity for the demonstration.
(2) Load center equipment. The equipment shown here is not standard; it contains 3 magnetic circuit breakers and one Edison base fuse holder. This combination makes it possible to demonstrate the action of both circuit breakers and fuses.
(3) Four branch circuits, each ending in a combined pilot light and convenience receptacle. The pilot light is merely for showing that the circuit is energized. It should be red.
(4) Two hundred feet of 18/2 flexible cord with one end attached to an appliance plug and the other end connected to a multiple convenience receptacle (E) and a lamp base (D).
(5) Two hundred feet of 12/2 non-metallic sheathed cable with one end attached to an appliance plug and the other end connected to a multiple convenience receptacle and a lamp base.
(6) Two $7\frac{1}{2}$ watt, white incandescent lamps for use in the lamp bases connected to the 18/2 cord and 12/2 cable.

Equipment Needed Which is Not Illustrated

(1) Appliances for loading the circuits and on which the effects of the voltage drop will be apparent. For the best demonstration, the appliances will be needed in pairs. For example, there might be 2 identical fans, 2 identical non-automatic toasters, and 2 identical radiant heaters with 1000 watt elements. Other useful appliances might include a 1/4 hp motor with a simple, home-made prony brake, 2 identical glass coffee-makers, 2 identical non-automatic hand irons, 2 identical vacuum cleaners with manometer tubes to show their suction, etc.
(2) A supply of different sizes of Edison base fuses for use in the fuse holder in the load center, and a supply of different sizes of Fusetrons (not Fusestats) for use in the same holder.

C. Demonstrating the Cause of Voltage Drop and its Effect on the Operation of Equipment

Before any demonstration of this type is given before a group of people it should be gone through completely in private to make sure that the equipment is properly assembled and that the differences being shown are apparent enough to be clearly seen by observers. Small electrical loads on wires produce relatively small voltage drops and the demonstrator must know in advance the amount of load needed, in terms of the equipment that he is using, to produce an effect that is clearly apparent.

(1) The demonstration equipment is explained to the audience so that the audience will understand what is happening as the demonstration proceeds.

(2) The feeder cable is connected to a source of 110 to 120 volt electricity with the circuit breakers open and no fuse in the fuse holder. The attention of the audience is called to the fact that there is no visible change.

(3) The 15 ampere and the 20 ampere circuit breakers are closed. The pilot lights on the two circuits connected through those breakers will light immediately. The audience should clearly see this and realize that the lighted pilots mean that those two circuits are energized.

(4) The 200 feet of 18/2 cable is plugged into one of the energized circuits and the 200 feet of 12/2 non-metallic, sheathed cable is plugged into the other. The two $7\frac{1}{2}$ watt, white bulbs on the other ends of these wires will then light, showing the audience that both of these coils of wire are energized. There will be no apparent difference in the brilliance of the two $7\frac{1}{2}$ watt bulbs and this should be called to the attention of the observers. This indicates that both 18/2 cord and the 12/2 cable adequately supply the $7\frac{1}{2}$ watt bulbs.

(5) One of the two identical fans is plugged into the receptacle on the end of the 18/2 cord and the other into the receptacle on the 12/2 cable. Both fans appear to run normally and there is still no apparent difference in the brilliance of the $7\frac{1}{2}$ watt bulbs.

(6) One of the 1000 watt heating elements, which may be in a hot plate, a radiant heater, or some other device with a visible element, is plugged into the outlet of the 18/2 cord and the other identical element into the outlet on the 12/2 cable. A noticeable dimming of the $7\frac{1}{2}$ watt light on the 18/2 cord will be evident. If the fans are running on slow speed, it will be noticed that the fan connected to the 18/2 cord is running definitely slower than the other one. After the two heating elements have had time to heat, it will be noticed that the element connected to the 18/2 cord is obviously less hot than the other. The light, the fan, and the heating element on the 12/2 cable all appear to be operating normally. Apparently the small wire is over loaded.

(7) Add the two identical, non-automatic toasters to the groups of appliances already connected. Call the attention of the audience to the fact that the $7\frac{1}{2}$ watt bulb on the 18/2 cord is now giving

definitely poor light by comparison with the other bulb. After the heating elements have had time to adjust to their new temperatures, let the audience see that the 1000 watt element on the 18/2 cord is now performing even poorer by comparison with the other one than it was previously. Place slices of bread simultaneously in the two toasters. When the bread in one begins to smoke, turn the slices in both. When one of them smokes again, remove the slices and let the audience compare the results of operating toasters on a loaded small wire and on an equally loaded larger wire.

(8) Give the individuals in the audience an opportunity to place their hands on the two coils of wire (18/2 cord and 12/2 cable). Call to their attention that the excess heat in the coil of 18/2 wire was produced by electricity used in the wire rather than in the appliance, and that although it registered on the meter, no benefit was received from it.

(9) Explain to the group that conditions were deliberately exaggerated in the demonstration; that on their farms they will seldom have situations as bad as was demonstrated by the 18/2 wire, but that they do have bad situations due to inadequate wires between and in their buildings. Make clear to the group that this is not a demonstration of how to wire, but that it merely shows the causes of voltage drop and the effects of voltage drop on the operation of equipment. The noticeable heat in the coil of 18/2 wire can be used to point out the dangers of overloading circuits.

(10) There are many possible variations to this demonstration. Many different types of equipment might be used to load the wires. Portable voltmeters might be plugged into the receptacles at the ends of the two coils of wire to show the greater drop in the 18/2 wire. This might be good before high school and vocational classes, but before adult farm groups, the actual operation of the equipment is far more effective than readings on meters with which the groups are not very familiar. Light meters and bulbs larger than the $7\frac{1}{2}$ watt ones might be used to show differences in light output, but, again, meters are much less effective teaching to people not familiar with them than actual visible differences in the brilliance of the bulbs. The fans have been suggested to show the effect of low voltage on motor driven equipment. This often can be more effectively demonstrated by a small motor equipped with a simple prony brake. Only one motor would be used. It would be alternately plugged into the outlets on the 18/2 cord and the 12/2 cable to show differences in starting power and break-down torque.

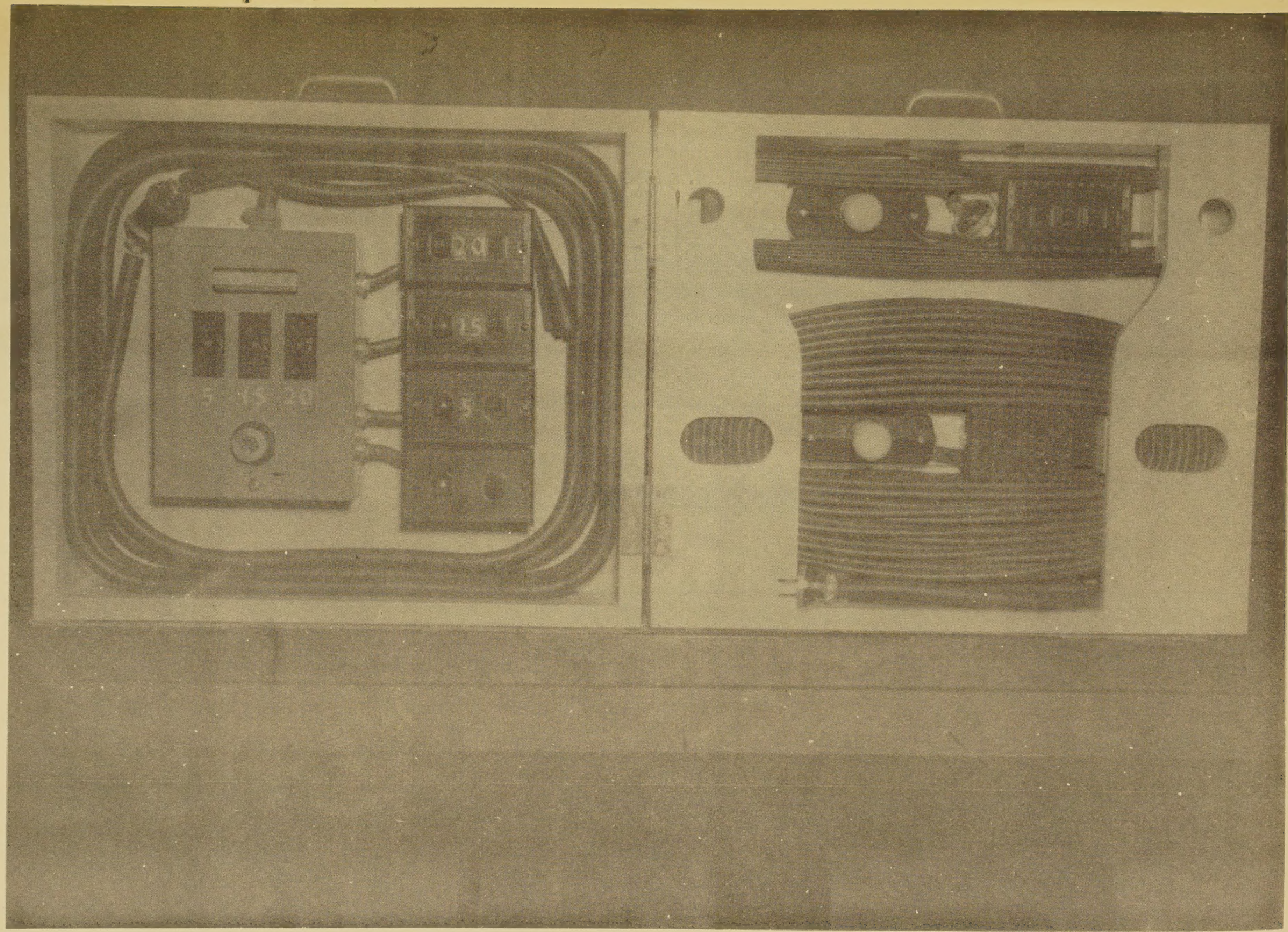
(11) The audience should be fully aware that the 18/2 cord used in this demonstration is not suitable for building wire, that the 18/2 cord and 12/2 cable are compared because larger sizes could not be overloaded enough to show the differences when fed through most building wires, and that the 18/2 cord is not protected by the circuit breaker used. The demonstrator should not leave the heavy load on the 18/2 cord long enough to destroy the cord.

D. Demonstrating the Operation of Fuses and Circuit Breakers

(1) For this demonstration the coil of 12/2 cable is not used since it could not be overloaded through the 20 ampere breaker or a 20 ampere fuse. The receptacle on the end of 18/2 cord is used for the addition of load to cause the breakers to trip and the fuses to blow. The plug on the other end of the 18/2 cord is plugged into the receptacles on the respective branch circuits as each breaker or fuse is being demonstrated.
A 5 ampere fuse or breaker provides proper protection for the 18/2 cord.

(2) Proper 5 ampere protection should be demonstrated first to show how this prevents dangerous overloading of the wire. Larger fuses and circuit breakers should then be used to show how they allow loads beyond the safe limit.

(3) Connecting through a 5 ampere fuse a motor which draws somewhat less than 5 amperes while running will demonstrate that fuses that would give running protection to motors will not allow them to start. Replacing the fuse with a 5 ampere Fusetron will show how time-lag fuses can be used to give this protection. Circuit breakers provide the needed time-lag, and this can be demonstrated.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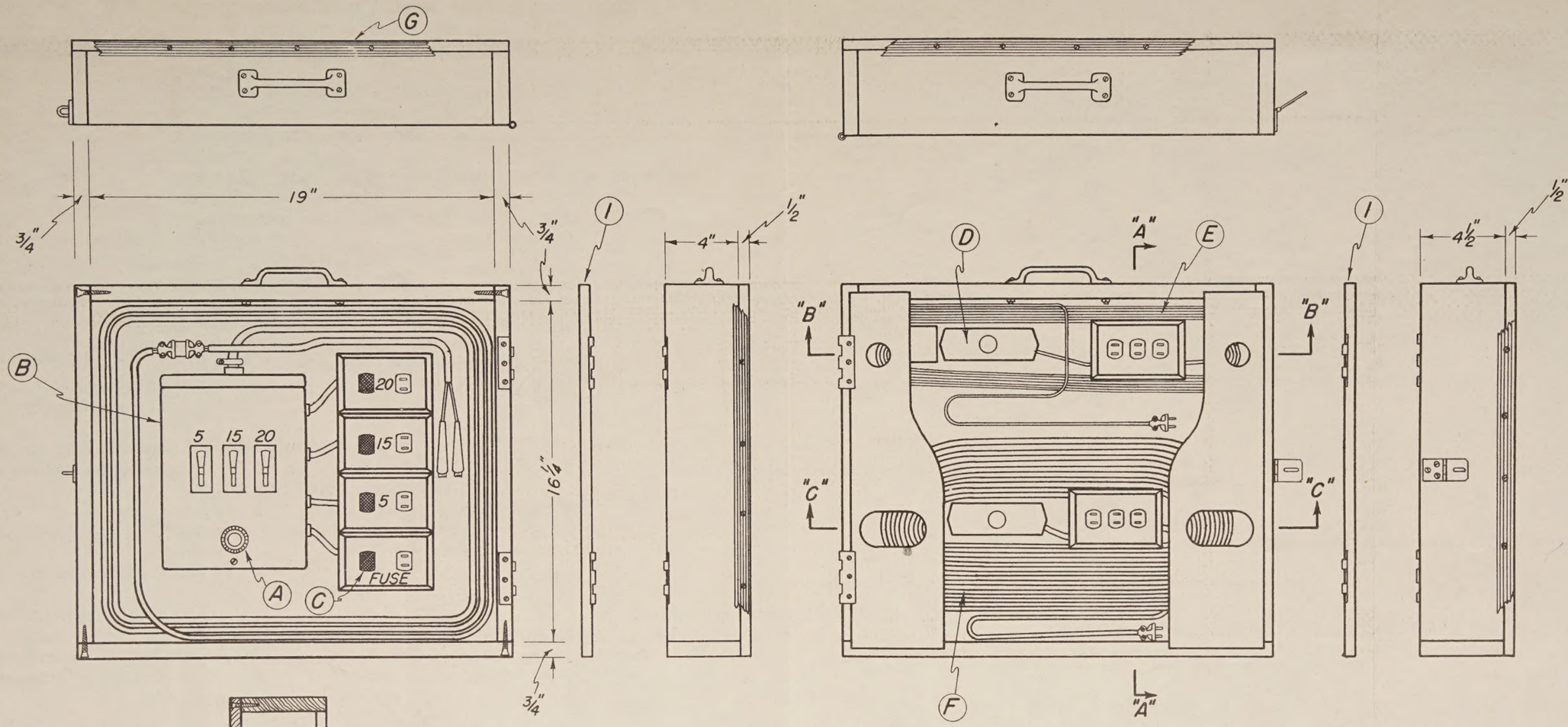
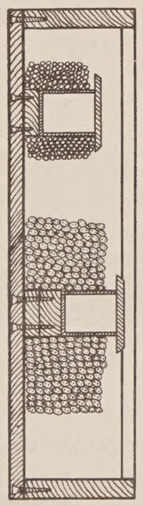
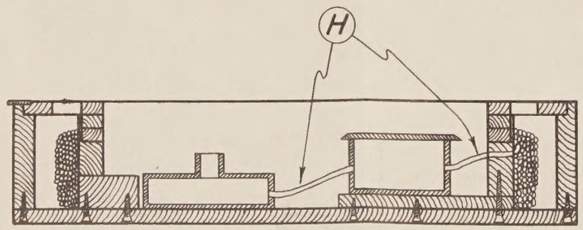
VOLTAGE DROP AND PROTECTIVE DEVICE DEMONSTRATION PANEL





Section "A-A"



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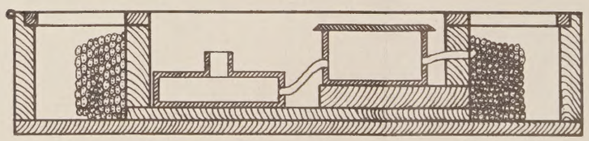

Section "C-C"

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Designed by: Applications and Loans Division
Drawing by: Technical Standards Division

LOW VOLTAGE AND PROTECTIVE DEVICE DEMONSTRATION PANEL

List of Materials

Lumber:

2 pieces	3/4" x 3-1/2" x 17"
1 piece	3/4" x 3-1/2" x 19"
1 piece	3/4" x 3-1/2" x 20-1/2"
2 pieces	3/4" x 4" x 17"
1 piece	3/4" x 4" x 19"
1 piece	3/4" x 4" x 20-1/2"

Plywood:

2 pieces	1/2" x 4-1/2" x 17"
4 pieces	1/2" x 17-3/4" x 20-1/2"

Note: Interior blocking to be cut as required. The lumber used in the actual construction is 3/4" boards and 1/2" plywood. Other thicknesses may be used as long as the inside dimensions are not changed.

Other cabinet materials:

2 each	Handles (brass or other metal) with bolts.
4 sets	1-3/4" x 2-1/2" loose pin, butt hinges.
13 ft.	3/4" x 3/4" metal corner mold.
Wood screws as required.	
Hasps or other fasteners as required.	

Electrical Equipment:

1 each	Circuit breaker cabinet, dead front, (modified) with Edison base fuse holder.
1 each	Circuit breaker, 20 ampere
1 each	Circuit breaker, 15 ampere
1 each	Circuit breaker, 5 ampere
1 box (mixed sizes)	Fuses, 5 - 20 amperes
1 box (mixed sizes)	Fusetron
4 each	Convenience receptacle with pilot light and one outlet.
2 each	Battery clips, rated 40 amperes, with insulated grips.
3 each	2 prong plug, heavy duty.
1 each	Plug receptacle, heavy duty.
2 each	Multiple convenience receptacle (3 outlets)
2 each	Lamp base
2 each	7-1/2 watt white incandescent lamp
25-30 ft.	10/2 or 12/2 heavy duty flexible cord
200 ft.	18/2 flexible cord (rubber covered lamp cord)
200 ft.	12/2 non-metallic sheathed cable (Super-PVX or equivalent used with these dimensions of box)

PARTS LETTERED ON DRAWING

A - Edison base fuse holder

B - Circuit breaker cabinet, dead front (modified)

C - Pilot light (red lens)

D - Lamp base

E - 200 Feet 18/2 flexible cord

F - 200 Feet 12/2 non-metallic sheathed cable

G - Aluminum corner mold

H - Interior connections - convenience outlet to lamp holder

I - Panel covers